UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED PHYSICS AND ENGINEERING MATHEMATICS

MODULE PHY1DB1

CAMPUS DFC

EXAM NOVEMBER 2015

DATE: 13/11/2015 **SESSION** 08:30 -11:30

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DURATION: 3 HOURS **MARKS:** 135

NUMBER OF PAGES: 18 PAGES

INSTRUCTIONS

Answer all the questions.

Calculators are permitted.

Answer SECTION A on UJ multiple choice answer sheet provided.

Answer SECTION B in the answer book provided.

SECTION A

1. Which of the following is a measure of the random motions of the components of a substance?

   A. Energy
   B. Frictional heating
   C. Temperature
   D. Heat

2. Which of the following is exothermic?

   A. A reaction in which the products are higher in potential energy than the reactants
   B. The melting of a solid
   C. The condensation of a gas
   D. Rolling a ball up a hill

3. Consider a 2 m long brass rod and a 1 m long aluminium rod. When the temperature is 22 °C, there is a gap of 1.0×10^{-3} m separating their ends. No expansion is possible at the other end of either rod. At what temperature will the two bars touch?

   A. 12.4^0C
   B. 14.4^0C
   C. 16.4^0C
   D. 18.4^0C

4. A steel rod has a length of exactly 20 cm at 30 ^{0}C. How much longer is it at 50 ^{0}C? [$\alpha_{Steel} = 11 \times 10^{-6}$ /^{o}C]

   A. 1.4×10^{-3} cm
   B. 2.4×10^{-3} cm
   C. 3.4×10^{-3} cm
   D. 4.4×10^{-3} cm

5. By how much does the volume of an aluminium cube 5.00 cm on an edge increase when the cube is heated from 10.0 ^{0}C to 60.0 ^{0}C? [$\alpha_{Aluminium} = 23 \times 10^{-6}$ /^{o}C]

   A. 0.23 cm^3
   B. 0.33 cm^3
   C. 0.43 cm^3
   D. 0.53 cm^3

6. The Pyrex glass mirror in the telescope at the Mt. Palomar Observatory has a diameter of 200 inches. The temperature ranges from -10 ^{0}C to 50 ^{0}C on Mt. Palomar. Determine the maximum change in the diameter of the mirror. [$\alpha_{Pyrex} = 3.2 \times 10^{-6}$ /^{o}C]

   A. 1.8×10^{-2} inches
   B. 2.8×10^{-2} inches
   C. 3.8×10^{-2} inches
   D. 4.8×10^{-2} inches

7. Calculate the mass of ice that will melt if 1000.0 g of iron at 500.0 °C is dropped into an ice-water mixture. The heat of fusion of water is 334.166 J/g. Specific heat for iron is 0.448 J/g °C. Assume that there is enough ice such that some is left after thermal equilibrium is achieved.

   A. 370.3 g
   B. 470.3 g
   C. 570.3 g
   D. 670.3 g

8. Electric power companies sell electrical energy by the KWh, where 1 kWh = 3.6×10^6 J. Suppose that it costs $0.15 per kWh to run an electric water heater in your neighbourhood. How much does it cost to heat 75 kg of water from 15 ^{0}C to 43 ^{0}C to fill a bathtub? The specific heat of water is 4180 J/kg ^{0}C.

   A. $0.36
   B. $0.46
   C. $0.56
   D. $0.66

9. How much thermal energy is absorbed by 1.00×10^2 g of ice at -20.0 ^{0}C to become water at 0.0 ^{0}C. The specific heat of ice is 2060 J/kg ^{0}C and the latent heat of fusion of ice is 3.34×10^5 J/kg.

   A. 2.75×10^4 J
   B. 3.75×10^4 J
   C. 4.75×10^4 J
   D. 5.75×10^4 J

10. An expansion valve does work on 100 g of water. The system is isolated and all the work is used to convert the 90 ^{0}C of water into water vapor at 110 ^{0}C. How much work does the expansion valve do on the water? The specific heat of water is 4180 J/kg ^{0}C, the specific heat of water vapor is 2020 J/kg ^{0}C and the latent heat of vaporization of water is 2.26 x 10^6 J/kg.

A. 100 kJ
B. 200 kJ
C. 300 kJ
D. 400 kJ

11. For waterfall with a height of 125.0 m, calculate the temperature difference between the water at the top and the bottom of the fall. Assume that the potential energy of the water is all converted to thermal energy. The specific heat of water is 4180 J/kg ^{0}C.

A. 0.193 ^{0}C
B. 0.293 ^{0}C
C. 0.393 ^{0}C
D. 0.493 ^{0}C

12. The kinetic energy of a compact car moving at 100 km/h is 2.9 x 10^5 J. To get an idea of the amount of energy needed to heat water, how many liters of water would 2.9 x 10^5 J of energy warm from room temperature (20.0 ^{0}C) to boiling point (100.0 ^{0}C). 1 L of water has a mass of 1 kg and the specific heat of water is 4180 J/kg ^{0}C.

A. 0.47 L
B. 0.77 L
C. 0.87 L
D. 0.97 L

13. A 1500 kg automobile comes to a stop from 25 ms^{-1}. All the energy of the automobile is deposited in the brakes. Assuming that the brakes are about 45 kg of aluminium, what is the change in temperature of the brakes? The specific heat of aluminium is 897 J/kg ^{0}C.

A. 12 ^{0}C
B. 14 ^{0}C
C. 16 ^{0}C
D. 18 ^{0}C

14. An electric immersion heater (3.00×10^2 W) is used to heat a cup of water. The cup (3.00×10^2 g) is made of glass and contains 250 g of water at 15 ^{0}C. How much time is needed to bring the water to the boiling point (100 ^{0}C)? Assume that the temperature of the cup is the same as the temperature of the water at all times and that no thermal energy is lost to the air. The specific heat of water is 4180 J/kg ^{0}C and the specific heat of glass is 840 J/kg ^{0}C.

A. 2.2 minutes
B. 3.2 minutes
C. 6.2 minutes
D. 7.2 minutes

15. A 750 kg car moving at 23 ms^{-1} brakes to a stop. Assume that all kinetic energy is transformed into thermal energy. The brakes contain about 15 kg of iron, which absorbs the energy. What is the increase in temperature of the brakes? The specific heat of iron is 450 J/kg ^{0}C.

A. 19 ^{0}C
B. 29 ^{0}C
C. 39 ^{0}C
D. 49 ^{0}C

16. A soft drink from Australia is labelled *Low-Joule Cola*. The label says “100 mL yields 1.7 kJ”. The can contains 375 mL of cola. Chandra drinks the cola and then wants to offset this input of food energy by climbing stairs. How high must Chandra climb if her mass is 65.0 kg?

A. 1.0×10^0 m
B. 1.0×10^1 m
C. 0.10×10^0 m
D. 0.10×10^1 m

17. To make iced tea, you brew the tea with hot water and then add ice. If you start with 1.0 L of 90 ^{0}C tea, how much ice is needed to cool it to 0 ^{0}C. 1 L of water has a mass of 1 kg. The specific heat of water is 4180 J/kg ^{0}C and the latent heat of fusion of ice is 334 kJ/ kg.

A. 1.1 kg
B. 2.1 kg
C. 3.1 kg
D. 4.1 kg

18. A 2.2 kg block of ice slides across a rough floor. Its initial velocity is 2.5 ms^{-1} and its final velocity is 0.50 ms^{-1}. How much of the ice melted as a result of the work done by friction? The latent heat of fusion of ice is 334 kJ/ kg.

A. 1.0×10^{-5} kg
B. 2.0×10^{-5} kg
C. 3.0×10^{-5} kg
D. 4.0×10^{-5} kg

19. During a game, the metabolism of basketball players often increases by as much as 30.0 W. How much perspiration must a player vaporize per hour to dissipate this extra thermal energy? The latent heat of vaporization of water is 2.26×10^{6} J/kg.

A. 0.0278 kg
B. 0.0378 kg
C. 0.0478 kg
D. 0.0578 kg

20 A ray of light passes from air (n = 1.000) into cubic zirconia at an angle of 46.9^{0} to the normal. The angle of refraction is 19.4°. What is the index of refraction of cubic zirconia?

A. 1.2
B. 1.4
C. 1.5
D. 2.2

21. A ray of light passes from air (n = 1.000) into ice (n = 1.314) at an angle of 23.7^{0} to the normal. The refracted ray of light then passes from ice into glycerine (n = 1.477). What is the angle of refraction of the ray of light in glycerine?

A. 12.8^{0}
B. 13.8^{0}
C. 14.8^{0}
D. 15.8^{0}

22. A ray of light passes from air (n = 1.000) into carbon disulfide (n = 1.628) at an angle of 55.6^0 to the normal. The refracted ray of light then passes from carbon disulfide into water (n = 1.333). What is the refracted angle in the water?

A. 18.2^0
B. 28.2^0
C. 38.2^0
D. 48.2^0

23. An object 4.6 cm in height is placed 22.5 cm on the left side of a concave lens. The focal length of the lens is 16.2 cm. What is the height of the image? Is it upright or inverted?

A. h_i = 1.9 cm ; the image is upright
B. h_i = 1.9 cm ; the image is inverted
C. h_i = 19 cm ; the image is upright
D. h_i = 19 cm ; the image is inverted

24. A 10.0 cm object is placed at 18.0 cm from a converging lens perpendicular to its main axis. The focal distance of the lens is 12.0 cm. Find the image distance, magnification, and state if the image is real or virtual.

A. d_i = 36.0 cm; m = - 2.00; the image is real
B. d_i = 36.0 cm; m = - 2.00; the image is virtual
C. d_i = 20.0 cm; m = - 2.00; the image is real
D. d_i = 20.0 cm; m = - 2.00; the image is virtual

25. A 5.0 cm object is placed at 10.5 cm from a converging lens perpendicular to its main axis. The focal length of the lens is 21.0 cm. Find the image distance, magnification, and state if the image is real or virtual.

A. d_i = -21.0 cm; m = 2.00; the image is real
B. d_i = -21.0 cm; m = 2.00; the image is virtual
C. d_i = 36.0 cm; m = - 2.00; the image is real
D. d_i = 36.0 cm; m = - 2.00; the image is virtual

26. A converging lens forms a real image that is 4.00 times greater than the object at 60.0 cm from the lens. Find the focal length of the lens and the object size if the image size is 20.0 cm.

A. f = 12.0 cm and h_o = 5.0 cm
B. f = 15.0 cm and h_o = 10.0 cm
C. f = 20.0 cm and h_o = 5.0 cm
D. f = 12.0 cm and h_o = 10.0 cm

27. A 14.0 cm object is placed at 8.0 cm from a diverging lens perpendicular to its main axis. The focal length of the lens is 12.0 cm. Find the image distance, magnification, object size, and state if the image is real or virtual.

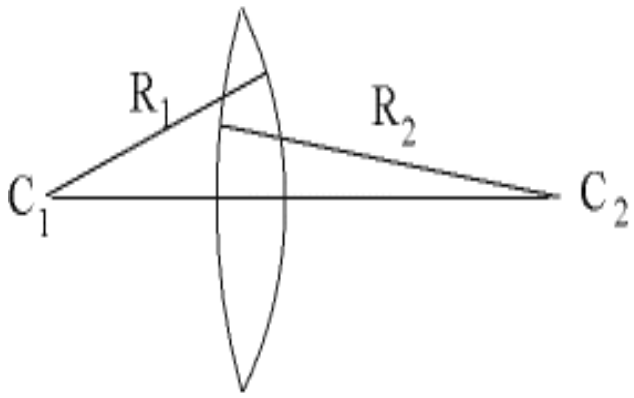
A. d_i = - 4.8cm; m = 0.60; h_o = 8.4 cm; the image is virtual

B. d_i = - 4.8cm; m = 0.60; h_o = 8.4 cm; the image is real

C. d_i = - 48cm; m = 0.60; h_o = 8.4 cm; the image is virtual

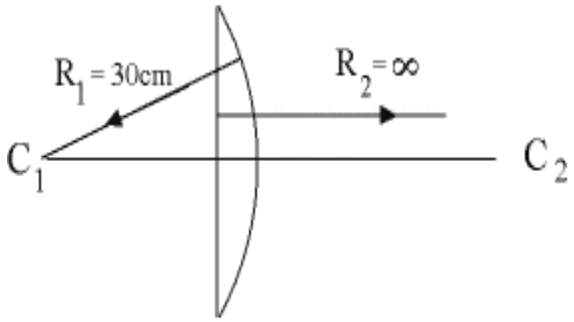
D. d_i = - 48cm; m = 0.60; h_o = 8.4 cm; the image is real

28. The radii of curvature of a convex-convex lens are 24 cm and 36 cm. The refractive index of glass is 1.50. Find its focal length.



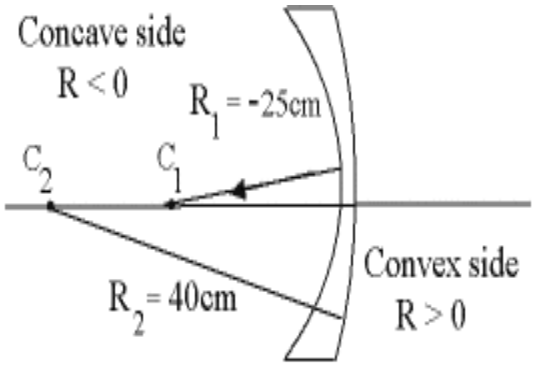
A. 19 cm
B. 29 cm
C. 39 cm
D. 49 cm

29. The radius of curvature of the convex side of a convex-flat lens is 30.0 cm. The refractive index of glass is 1.50. Find its focal length.



A. 20 cm
B. 40 cm
C. 60 cm
D. 80 cm

30. The radius of curvature of the concave side of a concave-convex lens is 25.0 cm and that of its convex side is 40.0 cm. The refractive index of glass is 1.50. Find its focal length.



A. -113 cm
B. -123 cm
C. -133 cm
D. -143 cm

31. Light enters the side of a PlexiglasTM prism (n = 1.488), which has an apex angle of 30.0°, at an angle of incidence of 45.0°. Determine the angle of deviation for the light after it has passed through the prism

A. 18.1°
B. 28.1°
C. 38.1°
D. 48.1°

32. Light leaves the second interface of a crystal glass prism (n = 1.52), which has an apex angle of 60.0°, at an angle of refraction of 45°. Determine the angle of deviation for the light after it has passed through the prism.

A. 21°
B. 31°
C. 41°
D. 51°

33. Bright bands in interference fringes result from _____.

A. destructive diffraction

B. destructive interference

C. constructive diffraction

D. constructive interference

34. In a double slit experiment with slits 1.0×10^{-5} m apart, light casts the first bright band 3.0×10^{-2} m from the centre of a screen 0.65 m away. What is the wavelength of this light?

A. 510 nm

B. 390 nm

C. 430 nm

D. 460 nm

35. An argon ion laser with a wavelength of 476.5 nm is used as the light source in a double slit experiment. If the slits are 0.0190 mm apart and the screen is 0.800 m away, what is the separation between the central bright line and the first-order bright line?

A. 18.6 mm

B. 21.3 mm

C. 20.1 mm

D. 19.1 mm

36. According to the Rayleigh criterion, two stars can be resolved if the_____.

A. dark bands overlap precisely

B. dark band of the first star covers the dark band of the second one

C. central bright band falls on the dark band of the second star

D. central bright bands overlap

37. A diffraction grating on a spectrometer has 9.500×10^3 lines/cm. If light of a wavelength 432 nm is viewed through the spectrometer, what is the angle at which the light has a first order band?

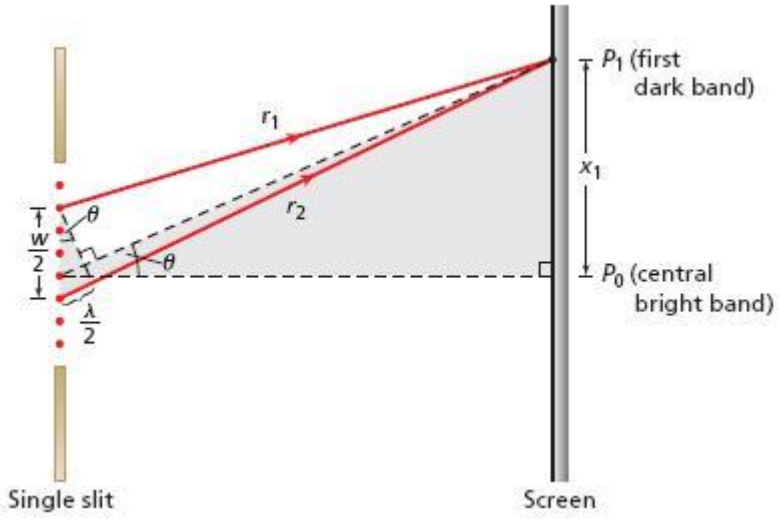
A. 51.3°

B. 65.8°

C. 39.7°

D. 24.2°

38. In the figure below, if light of wavelength 475 nm were shone through a slit of width 0.20 mm at a screen 0.60 m away, what would be the width of the central band?



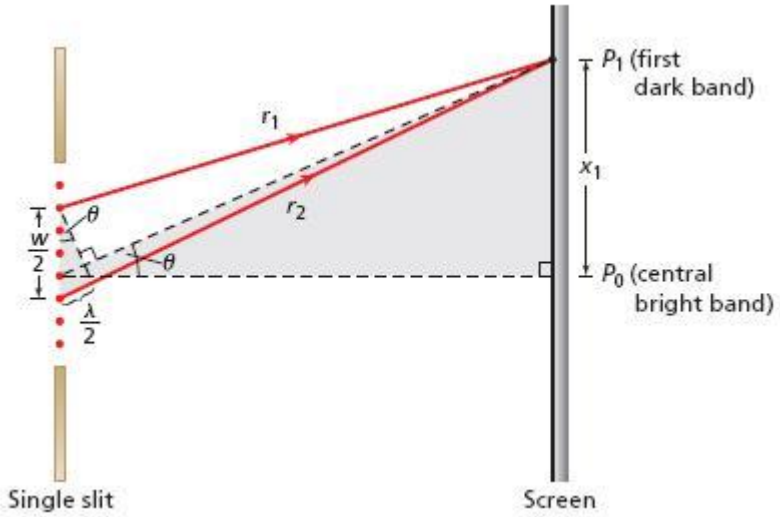
A. 28 mm

B. 1.2 mm

C. 7.1 mm

D. 1.8 mm

39. If light of wavelength 475 nm were shone through a slit of width 0.20 mm at a screen 0.50 m away as shown below, what would be the width of the central band?



A. 11 mm

B. 5.9 mm

C. 2.4 mm

D. 24 mm

40. A krypton ion laser with a wavelength of 524.5 nm illuminates a 0.045 mm wide slit. If the screen is 1.10 m away, what is the distance between the central bright band and the first dark band?

A. 0.13 m

B. 0.008 m

C. 0.010 m

41. A diffraction grating is labelled as having 11 000 lines/cm. What is the distance between the lines in the grating?

A. 9.1×10^{-7} cm

B. 9.1×10^{-5} cm

C. 8.7×10^{-5} cm

D. 9.6×10^{-7} cm

42. Violet light falls on two slits separated by 1.90×10^{-5} m. A first-order bright band appears 13.2 mm from the central bright band on a screen 0.600 m from the slits. What is the wavelength?

A. 318 nm
B. 418 nm
C. 518 nm
D. 618 nm

43. In a double-slit experiment, physics students use a laser of wavelength 632.8 nm. A student places the screen 1.000 m from the slits and finds the first-order bright band 65.5 mm from the central line. What is the slit separation?

A. 6.66 µm
B. 7.66 µm
C. 8.66 µm
D. 9.66 µm

44. You can observe thin-film interference by dipping a bubble wand into some bubble solution (n = 1.33) and holding the wand in the air. What is the thickness of the thinnest soap film at which you would see a black stripe if the light illuminating the film has a wavelength of 521 nm?

A. 196 nm
B. 296 nm
C. 396 nm
D. 496 nm

45. What is the thinnest soap film (n = 1.33) for which light of wavelength 521 nm will constructively interfere with itself?

A. 67.9 nm
B. 77.9 nm
C. 87.9 nm
D. 97.9 nm

46. A silicon solar cell has a non-reflective coating placed on it. If a film of silicon monoxide (n = 1.45) is placed on the silicon (n = 3.5), how thick should the layer be to keep yellow-green light of wavelength 555 nm from being reflected?

A. 65.7 nm
B. 75.7 nm
C. 85.7 nm
D. 95.7 nm

47. The mirrors have been removed from a kaleidoscope. The diameter of the eyehole at the end is 7.0 mm. If two bluish-purple specks on the other end of the kaleidoscope separated by 40 μm are barely distinguishable, what is the length of the kaleidoscope? Use λ = 650 nm and assume that the resolution is diffraction limited through the eyehole.

A. 0.2 m
B. 0.4 m
C. 0.6 m
D. 0.8 m

48. Suppose the *Hubble Space Telescope*, 2.4 m in diameter, is in orbit 1.0 x 10^5 m above earth and is turned to view Earth. If you ignore the effect of the atmosphere, how large an object can the telescope resolve? Use λ = 515 nm.

A. 1.6 cm
B. 2.6 cm
C. 3.6 cm
D. 4.6 cm

[48 x 2 = 96]

SECTION B

QUESTION 1

1.1 Differentiate between heat and temperature. (2)

1.2 A 4.00 x 10^2 g sample of water at 15.0 ^{0}C is mixed with 4.00 x 10^2 g of water at 85.0 ^{0}C. After the system reaches thermal equilibrium, 4.00 x 10^2 g of methanol at 15.0 ^{o}C is added. Assume that there is no thermal energy lost to the surroundings. What is the final temperature of the mixture? The specific heat of water is 4180 J/kg ^{0}C and the specific heat of methanol is 2450 J/kg ^{0}C. (4)

1.3 A 2.50 x 10^2 kg cast-iron car engine contains water as a coolant. Suppose that the engine's temperature is 35.0 ^{0}C when it is shut off, and the air temperature is 10.0 ^{0}C. The heat given off by the engine and the water in it as they cool to air temperature is 4.40 x 10^6 J. What mass of water is used to cool the engine? The specific heat of water is 4180 J/kg ^{0}C and the specific heat of iron is 450 J/kg ^{0}C. (4)

1.4 Two copper blocks, each with a mass of 0.35 kg, slide toward each other at the same speed and collide. The two blocks come to a stop together after the collision. Their temperatures increase by 0.20 ^{0}C as a result of the collision. Assume that all the kinetic energy is transformed into thermal energy. What was their speed before the collision? The specific heat of copper is 385 J/kg ^{0}C. (4)

[14]

QUESTION 2

2.1 State Snell's law. (1)

2.2 The speed of light in a material is 2.01 x 10^8 ms^{-1}. A ray of light leaving air (n = 1.000) enters the material at an angle of 35^o. At what angle is the ray refracted? (3)

2.3 A dentist uses a small mirror of radius 40 mm to locate a cavity in a patient's tooth. If the mirror is concave and held at 16 mm from the tooth, what is the magnification of the resulting image? (4)

2.4 A production line inspector wants a mirror that produces an upright image with magnification 7.5 when it is located 14.0 mm from a machine?

2.4.1 What kind of mirror would do this job? (2)

2.4.2 What is its radius of curvature? (4)

[13]

QUESTION 3

3.1 A single-slit diffraction experiment is set up with light of wavelength 420 nm incident perpendicularly on a slit of width 5.10 μm. The viewing screen is 3.20 m away. What is the distance between the center of the diffraction pattern and the second diffraction minimum on the screen? (3)

3.2 A spectroscope uses a grating with12000 lines/cm. Find the angles at which red light (632 nm) and blue light (421 nm) have first-order bright lines. (6)

3.3 The two headlights of an approaching automobile are 1.4 m apart. Assume that the pupil diameter is 5.0 mm and use a wavelength of 550 nm for the light. Also assume that diffraction effects alone limit the resolution so that Rayleigh's criterion can be applied.

3.3.1 At what angular separation will the eye resolve the two headlights? (3)

3.3.2 At what distance will the eye resolve the two headlights? (3)

[15]

FORMULA SHEET

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$m = \frac{-d_i}{d_o} = \frac{h_i}{h_o}$$

$$P = \frac{1}{f}$$

$$f = \frac{1}{2}R$$

$$\frac{1}{f} = (n-1)(\frac{1}{R_1} + \frac{1}{R_2})$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1\lambda_1 = n_2\lambda_2$$

$$n = \frac{c}{v}$$

$$c = f\lambda$$

$$c = 3 \text{ x } 10^8 \text{ ms}^{-1}$$

$$d \sin\theta = m\lambda$$

$$2nd = (m + \frac{1}{2})\lambda$$

$$2nd = m\lambda$$

$$d = \frac{1}{N}$$

$$\theta = \frac{1.22\lambda}{D} = \frac{d}{L}$$

$$\sin i_1 = n \sin r_1$$

$$\sin i_2 = n \sin r_2$$

$$D = (i_1 - r_1) + (i_2 - r_2)$$

$$n = \frac{\sin[\frac{D_m + A]}{2}}{\sin[\frac{A}{2}]}$$

$$Q = mc\Delta t$$

$$Q = mL$$

$$P = \frac{W}{t}$$

$$\Delta l = \alpha\, l\, \Delta T$$

$$\Delta A = 2\alpha\, A\, \Delta T$$

$$\Delta V = 3\alpha\, V\, \Delta T$$